Mr. James Milne, of the Forth and Clyde Navigation, remarked, through the Secretary, that ten years ago, and for some years after, he had occasion to give this subject his attention, in endeavouring to introduce steam power on the Forth and Clyde and Monkland Canals; and, at the third annual meeting of the Canal Association, held in Birmingham, on the 4th August, 1858, he exhibited drawings of steam engines for a canal goods lighter, for a canal and sea-going lighter, for an ice-breaker, and a single engine for a goods boat or mineral 'scow.' These boats and their machinery were thus described in the Proceedings of that meeting:—

"The canal goods lighter is one of a class which carry 80 tons; the engines are two 6¼ inch cylinders, with 10 inches stroke of piston: the boiler an upright tubular boiler, 3 feet diameter; weight of engines and boiler, with water, 2½ tons. The engines and boiler are capable of working to 100 lbs. pressure on the square inch; but 35 lbs. pressure in the cylinders is found sufficient for propelling the lighter, with cargo, at the rate of from 4½ to 5 miles an hour. The engines were completed in September, 1856, since which time they have been regularly at work; they were made of sufficient power to propel the lighter, and to tow one or two similar lighters; but the traffic the lighter has been employed in has not afforded opportunities for using the surplus power in towing. The engines and boiler, with stern-post and propeller, cost £320; a considerable proportion of the cost and also the weight being due to the surplus power.

"The ice-breaker, in addition to breaking the ice on the canal, is also used as a crane boat and service boat for the canal works. The steam engines for this boat were completed in May last, and consist of two cylinders 9½ inches diameter, with 15 inches stroke of piston, with two upright tubular boilers 3 feet diameter, all calculated for being worked to 100 lbs. pressure. Cost of engines, boiler, and propeller, £430.

"The engine for the goods boat or mineral scow is not yet put to work, but is contracted for. The engine, a single 6-inch cylinder, with 9 inches stroke of piston; the boiler (an upright tubular boiler) 2 feet 6 inches diameter, all to be capable of working to 100 lbs. pressure. It will not cost more than £150.

"All the vessels referred to were formerly towed by horses: they are the usual canal vessels, and have been and are being pierced and fitted for screw propellers. The canal and sea-going lighter is now being prepared for receiving the engines and propeller.

"Since the goods lighter was put to work in 1856, there have been five lighters fitted with steam power put to work on the canal by the canal traders."

Again, at the next meeting of this Association, on the 16th August, 1859, he furnished a report relative to these canal steamers, in which he observed that:—

"The following are the principal dimensions of engines, &c., of the canal craft above referred to (see next page):—

"There are now eighteen vessels propelled by steam working on the canal, and not fewer than half that number are being fitted with steam power for the canal.

"The length of the Forth and Clyde Canal, from Grangemouth on the Forth, to Bowling on the Clyde, is 35 miles, with a branch 4 miles in length to the Monkland Canal at Glasgow, joining the main canal at near the 26th mile from Grangemouth, and the Monkland Canal is 12 miles in length from Glasgow to Woodhall. The greater amount of the traffic on the Monkland Canal is

Name or Designation of Vessels.	Cargo carried in tons.	Number of Cylinders.	Diameter of Cylinders.	Stroke of Piston.	Maximum Pressure required in Cylinder for full cargo.	Diameter of Screw Propeller.	Pitch of Screw.	Boilers Upright, No. of.	Diameter of Boilers.	Height of Boilers from F. B. to Crown.	Length of Tubes.	Taper Tubes inside Diameter.	Heating Surface in square feet.	Speed with average Load. Miles per Hour.	Space occupied by Engines and Boilers from Stern Post to Bulkhead.	Time when put to work.
			ins.	ins.	lbs.	ft. in.	ft. in.		ft. in.	ft. in.	ft. in.	ins. ins.			ft. in.	
'Thomas' .	80	2	$6\frac{1}{4}$	10	35 to 40	3 6	4 0	1	3 0	7 6	3 6	$2\frac{1}{4}$ & $1\frac{3}{4}$	110	$4\frac{1}{2}$ to 5	11 0	Sept., 1856
'Marjory' .	35	1	6	9	45 to 50	2 8	3 3	1	2 6	5 8	2 6	$2\frac{1}{8}$ & $1\frac{3}{4}$	53	5 to 6	9 0	Feb., 1859
Ice Breaker	say 80	2	$9\frac{1}{2}$	15	. .	4 9	5 3	2	3 0	7 9	3 6	$2\frac{1}{4}$ & $1\frac{3}{4}$	220	3 to 6	13 0	May, 1858
120 ton Lighter	120	2	$9\frac{1}{2}$	14	To be worked to 60 lbs. at sea.	4 9	5 3	2	4 0	9 0	F. Boxes with Pouches	. .	200	5 in Canal 10 at Sea	13 0	Now being made.
Scow 'James'	60 to 70	1	7	9	60 to 75	3 0	3 4	1	2 6	5 8	2 6	$2\frac{1}{8}$ & $1\frac{3}{4}$	53	$2\frac{1}{2}$ to $4\frac{1}{2}$	8 6	Aug., 1859

from the Coatbridge and Gartsherrie mineral district, a distance of about 10 miles from Glasgow, and the usual carrying of minerals is by the scows, which are worked on the Forth and Clyde Canal by two boatmen, one horseman, and one horse; and on the Monkland (when carrying to Glasgow only) by one boatman, one horseman, and one horse; and the usual carrying on the Monkland Canal to Glasgow by the scows is, down loaded with from 55 tons to 60 tons, and up empty, which is done at a cost of about 9½*d.* per scow per mile, the scow loaded half-a-mile and empty half-a-mile.

"With steam power say for the 20 miles:—

	£	s.	d.
One boatman, @ 4*s.*	0	4	0
One engineman, @ 3*s.*	0	3	0
Coals, 4 cwt., @ 4½*d.*	0	1	6
Oil and tallow, 3*d.*, gasket and waste, 1*d.*	0	0	4
Cost of engine, £150, 5 per cent. on per day	0	0	6
Ditto for depreciation and repair	0	1	0
Cost per trip of 20 miles	£0	10	4

Gives about 6¼*d.* per mile. Some of the steam scows carry a lad for giving greater facility in passing the locks; wages of lad, say 2*s.* per day, which added, gives 12*s.* 4*d.*, or nearly 7½*d.* per mile; but this mileage, while it is more than an average day's work for a horse, is not a full day's work for the scow, with engine power, and this short journey may be taken as most unfavourable for the comparison of steam propulsion with horse haulage. The steam power gives a more just and favourable comparison on longer journeys, say from Coatbridge to Grangemouth, which gives 10 miles on the Monkland Canal, and 30 miles on the Forth and Clyde Canal, together 40 miles from Coatbridge to Grangemouth. This is a usual trip in the working of the mineral traffic, and the trip loaded 40 miles, and back empty 40 miles, in all 80 miles, is usually esteemed a week's work for a scow and crew towed by a horse, but the trip is sometimes done in five days by horse haulage, and with steam power the trip is accomplished in three days.

"Cost per trip by horse haulage, say—

	£	s.	d.
Five days of man and horse, with towing ropes, @ 7*s.* 6*d.*	1	17	6
Five days of 2 boatmen, each @ 4*s.*	2	0	0
	£3	17	6

"Cost per trip by steam power, say—

	£	s.	d.
Three days of 2 boatmen, each @ 4*s.*	1	4	0
Ditto engine driver, @ 3*s.*	0	9	0
Ditto per centage on £150, @ 5 per cent.	0	1	6
Ditto, ditto, for repairs, &c., 10 per cent.	0	3	0
Coals, 16 cwt., at 4½*d.*—6*s.*; oil, 1*s.*; gasket and waste, 4*d.*	0	7	4
	£2	4	10

"*It will be observed that on trips of such length as the above, there is a* great saving of time, and it is estimated that with trips of average distance two boats propelled by steam will do as much work as three boats towed by horses.

"The Forth and Clyde Canal, communicating with the Friths of Forth and Clyde, offers facilities for employing the carrying craft propelled by steam to advantage in carrying beyond the canal, and boats of the scow class furnished with hatches have sailed to Leith and to Greenock, distances of 24 miles and 12 miles from the termini of the canal."

The fact of steam power having been tried at various times on the Forth and Clyde and the Monkland Canals, from Symington's steamers in 1789,—the 'Charlotte Dundas' in 1801, and the more recent trials by other parties—did not favour the attempt made in 1855; and in his proposal to employ carrying steamers, with light high-pressure engines, he found that he had so far to conform to the instruction of the Canal Board, as to make the trial steamer of sufficient power to tow two lighters similar to the lighter in which the engines were fitted. To towing he would have had no objection but for the numerous locks on the navigation, and the delay which must take place at the locks, both to a tug with its fleet, and to promiscuous canal trade. On the Forth and Clyde Canal, which was 35 miles in length between the Frith of Forth and the Frith of Clyde, there were forty locks with a rise of about 8 feet each, and at distances apart of from 50 yards to 17 miles, lock to lock. On the Monkland Canal there were ten locks, eight of which were double locks, each having a lift of 12 feet, giving a rise of 96 feet, with basins between the pairs, the other two locks having a rise of $10\frac{1}{2}$ feet each, with a basin between. The locks being so placed, and thus numerous, and the canals being free to all traders on payment of tolls—with a considerable and increasing trade—and the Canal Company not being carriers, except in the single instance of a limited trade in goods, he considered that an attempt to collect and tow the various descriptions of craft belonging to the traders offered no chance of success, while he feared that towing the vessels in fleets might delay the general trade, and give just cause of complaint. He therefore, with the concurrence of the Canal Board, resolved on making a trial of carrying steamers with small high-pressure engines and screw-propellers, the engines being fitted as close to the stern of each vessel as practicable. The lighter 'Thomas,' which was fitted with engines and put to work in 1856, and carried 80 tons of cargo, was used for the goods-trade worked by the Canal Company. The engines and the boiler had been constantly at work since that time, and were still working most satisfactorily, but little repair having been needed either for the boiler or the engines, and no renewals either for the boiler, the fire-box, or the tubes.[1]

The application of steam power to the 'Thomas' having proved successful, engines were designed and fitted to the luggage-boat 'Marjory,' carrying 35 tons; to one of the canal ice-breakers; to masted lighters for canal and coasting trade, carrying 120 tons; and designs for a 'scow,' or mineral barge, carrying 60 tons on the Monkland Canal, and 75 tons on the Forth and Clyde Canal, all

[1] Some particulars of this lighter, by Mr. Neil Robson, M. Inst. C.E., are to be found in the Transactions of the Institution of Engineers in Scotland, vol. i., p. 49.

of which had proved successful, and had been the precursors of about seventy canal steamers now at work on the Canal, and from the Canal to the contiguous sea coasts.

The increase in the number of steamers on the Forth and Clyde Navigation Canal and the Monkland Canal was shown in the following table:—

1856	1 steamer.	1862	36 steamers.
1857	2 „	1863	44 „
1858	7 „	1864	50 „
1859	18 „	1865	58 „
1860	25 „	1866	70 „
1861	30 „		

Mr. Edwin Thomas said, through the Secretary, that the Regent's Canal Company, in the year 1854, issued an advertisement offering a premium of £100 for the best tug-boat which should be put in competition on a day to be appointed by them, and £50 for the next best boat. In August, 1855, a trial took place, which resulted in the first prize being awarded to Mr. Inshaw, of Birmingham, for the screw tug-boat 'Birmingham,' which was now the property of that Company, and which was, until June, 1865, constantly employed in hauling the barge traffic upon the summit level of their canal. The vessel was 6·68 feet wide, 70·68 feet long, and drew 3·50 feet of water. It was fitted with a multitubular boiler and an engine having a pair of cylinders 7 inches diameter, and was worked with steam at a pressure of 60 lbs. to 70 lbs. per square inch. Two screws of 4 feet pitch were fixed near to the stern end of the vessel, and were revolved in opposite directions to each other, by means of bevel wheels, in the proportion of two to one. (Plate 2, Figs. 2 and 3.) The capabilities of this vessel would appear from the following statement of the work performed on the 15th June, 1862:—Started at 6·15 A.M., and at 7·45 P.M. (13·5 hours) had run over 11·25 miles of canal, towing twenty barges, seventeen of which were laden with an aggregate amount of cargo of 931 tons. If to this be added the weight of the twenty vessels, which might be taken at an average of 15 tons each, the gross load would be 1,231 tons—exclusive of the weight of the tug. At one trip it hauled eight vessels, containing 421·5 tons of cargo, over a distance of 2·25 miles in 3 hours 45 minutes. The sectional area of the water way traversed, as compared with that of the vessels navigating the canal, was about 4 to 1; except for the portion of canal through the Maida Hill Tunnel, which was only about 2 to 1 for a distance of 270 yards. The cost of working that vessel for the eight months ending 31st May, 1865, was £344. 2*s.* The distance traversed was 3,519 miles; number of barges hauled 2,023; the gross amount of cargo conveyed was 59,738 tons, which, with the weight of the barges, each averaging 15 tons, made a total of 90,083 tons towed. The result of the work performed during the period stated was—

Cost per train mile, labour and repairs only	1·26	shilling.
„ „ „ fuel only	·70	„
„ „ „ including all charges	1·96	„
Cost per ton of cargo, labour and repairs only	·893	of a penny.
„ „ „ fuel only	·49	„
„ „ „ including all charges	1·383	„
Cost per ton, gross weight, labour and repairs only	·593	of a penny.
„ „ „ fuel only	·323	„
„ „ „ including all charges	·916	„

The consumption of fuel was rather large, owing chiefly to the want of a larger boiler.

From the consideration which Mr. Edwin Thomas had given to the question of applying steam power on the Regent's Canal, he was inclined to believe that it could not be economically employed by the canal traders, and therefore would not come into general use, unless some plan were adopted for combining the tug and cargo vessel, so that they might pass through the locks together, and be readily separated at the termination of the journey. His views on this subject were reported to the Canal Association in 1859 in the following words:—

"One suggestion I would offer on this subject, *viz.*, that the vessels to be propelled by this method of propulsion should be constructed in two parts; the total length not to exceed that of the present vessels in use, which are capable of passing through the locks in canals; the part containing the machinery should, I propose, be as short as it may be practicable to have it, and form the hinder or stern portion, and be fitted with the rudder; the stem or fore end of the vessel to be constructed of a circular, or any other shape that may be considered best. I also propose that the after or stern of the other portion be made exactly the reverse of the fore end of the first-mentioned vessel, so that the two parts may be joined together at those ends, and so form one continuous line, . . . the ends of the vessels being provided with couplings, for securing the vessels together and detaching them."

The advantages to be derived from this plan were, that the propelling machinery would not be restricted to one vessel, but could be applied to any vessel of a similar shape. By this arrangement it could be constantly kept at work, thereby effecting a considerable saving in the expense of haulage; besides obviating the necessity of a large expenditure in applying similar machinery to all vessels proposed to be propelled by the means referred to, or that of the ordinary screw. In this way he thought the chief impediment to the more general application of steam power to haulage purposes on canals would be removed.

Mr. Clegram said, although the Paper had been written about eight months, he did not know that he had much to add to it, except to state that one of the main difficulties, where two or three large vessels were towed together, was to keep the last vessel in line with those before it. That was remedied by adopting the practice of sending three or four rafts of timber behind the last vessel, which were found to have sufficient hold upon the way of the last vessel to keep it tolerably in line with those that preceded it, and in that manner the traffic had been conducted for the last four years. The total amount of work performed by four tugs, another one having been placed on the navigation recently, during three weeks in September, 1866, gave more advantageous results than those stated in the Paper. In those three weeks 35,280 tons of goods were moved 16 miles on the Canal by the four tugs, at the following cost:—

	£.	s.	d.
81 tons of coals at 14*s*.	56	14	0
Tallow, oil, cotton waste, &c.	9	0	0
Wages £3 2*s*. per week for each boat	37	4	0
Agents employed at each end of the Canal £130 a-year, say	8	0	0
Interest of money, and wear and tear, 15 per cent. per annum on £4,000, for three weeks	34	10	0
Total . . .	£145	8	0

These figures represented the actual outlay for working, except in the case of the amount charged for tallow, oil, cotton waste, &c., which was estimated. That cost of £145 8*s*., applied to the number of tons conveyed, came to not quite one-sixteenth of a penny per ton per mile, an economy beyond what was stated in his Paper, where it was said to be one-twelfth of a penny per ton per mile, showing that where steamers were regularly employed it became a very economical mode of moving vessels on the Canal.

Mr. E. Leader Williams said, his experience with reference to steam towing had been chiefly upon the river Severn, which was very different to tugging in still water, as there was a velocity of current of sometimes 5 miles an hour, and with a stream usually running down, when there were any freshets, at from 2½ miles to 4 miles an hour. Steam tugs had been used on the Severn for the last ten years. In the first instance the Commissioners had purchased one of a pair of tugs that had been employed in towing coal barges on the Thames, from London to Windsor, named the 'Enterprise,' the other being called the 'Perseverance.' The engines were from 30 HP. to 40 HP., with reefing paddle wheels.

The 'Enterprise,' when used on the Severn, answered well. She had brought from Gloucester trains consisting of twelve vessels, carrying cargoes of 30 tons each, at a rate of $2\frac{1}{2}$ miles to 3 miles an hour, against a stream running 2 miles an hour; and she had done that work very economically. He had not experienced on the Severn the difficulty alluded to in the first Paper, of keeping the train of vessels in line; this was no doubt owing to the action of the current against which the vessels were towed. For the first 2 miles out of Gloucester, the Severn was narrow and tortuous; but still he had no difficulty in bringing trains of twelve vessels behind the tug, reaching of course a considerable distance down the river; and while the tug was going in one direction, the tail of the train would sometimes be advancing in an opposite one. Nor had he experienced the difficulties mentioned with regard to passing locks. At the last lock he built on the Severn, he constructed, in connection with it, a large basin, with a pair of gates; so that by the use of the basin and the lock together, he had passed the steam tug and a train of nine vessels at the same time, and very expeditiously. A number of tugs of different construction had recently been introduced upon the Severn; but the most efficient he considered to be those which carried a cargo and towed as well. These were barges of 70 feet in length, 12-feet beam, and $3\frac{1}{2}$ feet draught of water; fitted with a pair of small, direct-acting engines, with cylinders $7\frac{1}{2}$ inches in diameter, and a length of stroke of 9 inches, working direct upon a pair of twin screws, 2 feet 6 inches in diameter. These vessels were capable of carrying 40 tons of cargo, and of tugging two or three canal boats with 30 tons of cargo in each. One of those steamers, with one canal boat behind her, had recently passed him, at the rate of $2\frac{1}{2}$ miles per hour, against a stream running from $3\frac{1}{2}$ to 4 miles per hour. He thought that was the most efficient mode of towing upon the Severn; and he recommended the adoption, in all cases, of engines on board the cargo vessel, instead of towing with detached tug vessels, as from his experience it was more economical in working than any other plan. For instance, the vessel he had alluded to burnt from $1\frac{1}{2}$ to 2 cwt. of Staffordshire coal per hour, when carrying 40 tons of cargo on board, and towing two canal boats carrying 30 tons each: that was moving 100 tons of cargo at an expenditure of 2 cwt. of coal per hour, which was the maximum consumption of fuel.

Mr. Pole wished to mention a case that had come before him some years ago, and which was interesting in some points regarding the use of steam power on inland canals. Some coal-owners trading on the Ashby-de-la-Zouch Canal, thinking that it offered a good opportunity for the use of steam haulage (there being a length of 30 miles without any lock), proposed to convey their coals in this way; and ordered a steamboat from Mr. Inshaw, of Birmingham, who, shortly before, had patented a mode of propulsion by a double screw at the stern, and had received a reward for his invention from the Regent's Canal Company. The Midland Railway Company, however, who were the proprietors of the Canal, refused to allow the boat to ply, on the ground that the steamer would damage the works of the canal, and interfere with the navigation; and this refusal led to the institution of proceedings in Chancery to test the rights of the case. As information on the subject was wanting, the Master of the Rolls directed that an Engineer should be instructed to make experiments upon the canal with the proposed boat, in order to see what effects might be expected to arise from its use, and this question was referred, by the consent of both parties, to Mr. Pole.

He accordingly tried the experiments in the month of May, 1859, with a boat called the 'Pioneer.' This was of the ordinary size used on the Canal, namely, about 70 feet long, 7 feet wide, and 4 feet deep. It had been fitted by Mr. Inshaw with a small steam engine of 6 HP., working twin screws at the stern; the machinery took up but little room, and left a large portion of the boat available for cargo: the boat was also intended to be used, if necessary, for towing. The experiments comprised many different varieties of conditions, in regard to the loading of the steamboat herself, and the number of other boats she had in tow; and the speed attained varied from $1\frac{1}{4}$ to 5 miles per hour; this speed varying, not only with the work done, but also with the section of the Canal, as it was found that where the Canal was diminished in sectional area the speed was retarded, and *vice versâ*.

The principal object of investigation was to observe the wave, or surge, caused by the passage of the steamer, and to estimate the effect it would have on the banks of the Canal. It was well known that any vessel propelled through a confined channel would produce, in passing, a wave or oscillation of the surface of the water, which would probably, in some shape or other, reach the banks, and cause an agitation of the water in contact with them. The magnitude and character of this agitation would, however, depend on the velocity and the other circumstances of the case. It might be so trifling as to be practically harmless, or it might take such a form as to be capable, if frequently repeated, of producing much injury. These two conditions merged so gradually into each other, that it was difficult to define the exact limit where the harmless state ended and the injurious one began; but, after careful observation, Mr. Pole was led to define the commencement of the injurious action to take place when the wave began to assume a breaking form, as distinguished from a convex shape, or wave of translation; and he conceived that when a continuous wave possessing this character in a marked degree accompanied the boat, injury to the banks, if not protected by masonry, or otherwise, must in time be expected to occur.

This point being fixed, observations were directed to the character of the wave produced at different speeds; but it then became necessary to draw a distinction between two causes, by either or both of which waves might be produced. These were, first, the actual passage of the boat through the water, which would be independent of the means of propulsion; and secondly, the action on the water of the propelling apparatus itself, which (as might be seen by watching the passage of a paddle-wheel steamer in the Thames) was capable, under certain circumstances, of creating a wave more formidable than that due simply to the motion of the body. Now it was a very decided result of these experiments, that the method of propulsion, by the double screw, did not, of itself, at any speed attained, give rise to any wave or surge at all injurious to the banks of the Canal. The two screws caused, of course, an agitation of the water in their wake, but this did not extend to the banks in any such form as could damage them. This second cause of wave was therefore dismissed from consideration. There then remained the wave arising from the passage of the boat through the water. This varied in some degree with the section of the Canal, and with the occurrence of curves in its direction; but it principally depended on the speed, and the following were the general results obtained. Up to a speed of 3 miles an hour no wave of an injurious character appeared. Between 3 miles and $3\frac{1}{2}$ miles an hour a breaking wave appeared occasionally in curves and shallows. Above $3\frac{1}{2}$ miles an hour the breaking wave became more continuous, and took a more marked character. At 4 miles an hour the injurious character of the wave became very decided. At 5 miles an hour, even in a much enlarged section, the wave was still more increased, breaking sometimes over the towing-path, and being followed by other waves in succession.

Mr. Pole did not find, in the course of these experiments, that the use of the steamer, with ordinary care, caused any injurious interference with the general navigation by other boats. It had the advantage of the absence of a tow-line, and of being able to pass on either side other boats at pleasure. The only inconvenience he could imagine was in case a tug was made to draw a long train of boats at a very slow speed, by which the passage of other traffic through narrow bridges, or tunnels, or locks, might be delayed. The result of the investigation was to lead Mr. Pole to recommend that the steamboats should be admitted upon the Canal, subject to such a limitation of their speed as would avoid the production of an injurious wave; and this recommendation was made an order of the Court of Chancery.

Mr. JOHN F. URE said, about about fourteen years since, when the modern improvements of widening and straightening the channel of the Clyde had made but little progress, that river, particularly in its upper part, was narrow, at low tide shallow, and in several places very tortuous. It was, however, used by vessels of almost all sizes and kinds then constructed, but by the largest at high water and in daylight only. The sailing vessels and large steamers always proceeded at a slow speed, but the river passenger steamers at the quickest rate they could travel. These passenger steamers were about 160 feet to 180 feet long, 16 feet to 18 feet beam, 5 feet to 6 feet draught, propelled by engines of 80 HP. to 100 HP.; and some, as the 'Iona,' a well-known specimen of these river steamers, exceeded these dimensions and power. The channel of the river in the upper part, near Glasgow, at low tide, was about 120 feet to 150 feet wide at the level of the water, with sloping sides protected by stone, and about 10 feet deep. These steamers in the open sea attained a speed of from 16 miles to 18 miles per hour; but in the narrowest and shallowest parts of the low-water channel the rate did not exceed 8 miles to 9 miles per hour, and at this speed a very great swell and surge in the water were produced. It was quite usual, at such times, to observe the water commencing to rise when one of these vessels was 2 miles or 3 miles off. This it did gradually, increasing as the steamer approached, and more rapidly near the vessel, till the wave broke, which it generally did opposite the steamer, but always upon the shoal water adjoining the river walls, against which it accumulated and was alone high; in the centre of the river it was inconsiderable. Upon the shore at the base of the walls, the hollow of the wave was considerably under low water. That part of the wave in the shoal water broke with great violence against the river walls, and necessitated the use of heavy whinstone rubble facing, from 2 feet to 3 feet thick, proceeding from below to above high water, and hand-built on the face, to protect the banks, and prevent them from being washed away. This great surge being the governing strain on the works, attention did not require to be directed to the lesser strains produced by the other vessels moving at slower speeds.

The scouring action produced by the surge from these steamers extended to the bed of the river. As an instance, it might be mentioned, that although the steamers were compelled to slacken speed when within a distance of a quarter or half a mile from where the diving-bell was in operation, yet it was necessary to raise the bell several feet. This scour was one of the principal means of enlarging the navigable channel; for example, on a length of 7 miles below Glasgow Harbour, where the river walls were tolerably perfect, and the surge produced by the motion of these vessels was therefore confined, the soil being of various kinds, but mostly sand, the navigable channel was increased during the fourteen years, 1839 to 1853, below low-water level to the extent of 1,176,035 cubic yards, of which only 459,952 cubic yards were removed by dredging, the remaining 716,083 cubic yards of enlargement being due to the scouring action produced by these vessels moving at the highest speed possible in such a channel. It might be said that this increase was due to other causes, as the scouring action of the tide, freshes, &c.; but Mr. Ure was quite satisfied that the enlargement was not due to these causes. One means he took to ascertain this was, to have the increased capacity of channel when dredging a particular work, where the tide did not exceed ½ a mile an hour, measured at regular intervals in the river, and the quantity produced in embankment on the shore; when he found the quantity so produced in the embankment uniformly less, whether the work was performed in the dry summer or wet winter weather. Speaking from recollection, he believed from 20 to 25 per cent. was washed away in the performance of the work. The length of the river in which these results were produced might be divided into two parts: the upper part of 2½ miles next the harbour, where a more considerable quantity of dredging had been performed, partly in straightening the bends, &c., had been increased in capacity 588,880 cubic yards with a dredging of 383,200 cubic yards; and in the lower 4½ miles, where the main, or only, dredging had been to remove the shoals, as the scour produced a general enlargement, an increased capacity of 587,155 cubic yards was effected with a dredging of 76,752 cubic yards. A similar enlargement had taken place in the remainder or lower part of the channel of the river; but being wider and its walls less perfect, in some cases there being none at all, the increased capacity due to the scour was not to the same extent.

The early part of the wave, the part before it commenced to break, he considered was a wave of oscillation, but after it commenced to break, a wave of translation, moving with great force. He was satisfied that it was common, at the period referred to, for such waves in the narrow part of the river at low water, especially when the steamer was of the largest size and approached one side of the river, to measure (vertically), from the hollow in the channel to the crest on the wall, quite 8 feet or 10 feet. This wave was still considerable on the Clyde in the narrow parts at low tide; but with the increased channel, both in depth and width, it was much less than formerly.

With these views he did not think any great speed could be attained in a canal or limited river channel, by vessels of large size; and he believed that if such vessels were propelled beyond a slow rate, their progress would produce abrasion both of the banks and bed of the navigation.

Mr. G. H. PHIPPS said, about twelve years ago experiments were tried under his direction upon the Stoke Canal, in Staffordshire, with the system of propulsion by the ejection of water. He did not think it was tried as it ought to have been, and therefore it was no discredit to that system that it was not then successful. The conclusion arrived at was that it was not superior to the common screw. He had designed a screw which was so arranged that it could be raised and lowered, by being fixed on a shaft with a universal joint, to suit the varying draught of the boat, that being one of the difficulties of canal navigation. With a vessel of that kind good service was done, and the expense was just about the same as the cost of haulage by horse power; but there being only one of those vessels, it was insufficient as a system, and the consequence was, from various reasons, it was not carried further. It appeared to him that a necessary element to make this system advantageous was a considerable length of canal without locks. On the Grand Junction Canal, where there were many locks, great delay and loss must necessarily arise; and this would also be the case where the canal was of small sectional area. With regard to the economy of screw propulsion in a narrow canal, no doubt the screw worked to great disadvantage from the enormous slip under such circumstances. It was well known that a high amount of duty was only obtainable with a screw when it was put in rapid motion, whereby it got hold of a great deal of water to operate upon. In a vessel going only 2 miles an hour, the screw operated on the same water over and over again. On the Grand Junction Canal the speed when towing one vessel did not exceed 3 miles or $3\frac{1}{2}$ miles an hour: there must therefore be a loss of power in that application. He thought it might be worthy of investigation, whether in such an instance as this—though he considered in larger cases the Ruthven system a bad one—with a narrow section and slope of bank of the ordinary kind, some system like that of Ruthven, producing momentum by a certain quantity of weight taken in per second, might not be more advantageous than the common screw.

Mr. E. E. ALLEN said, with regard to steam tugs on the Thames, some years ago his attention was called to the subject by Mr. Thomas Page (M. Inst. C.E.), then acting for the late Prince Consort, who was desirous of having tug boats on the Thames at Windsor, to avoid the necessity of horses passing by Windsor Castle. Mr. Allen, after examining many tug boats in England and Scotland, came to the conclusion that the best thing for the Thames was the paddle wheel, with feathering floats, immersed 3 feet below the surface. He had an experimental boat built with engines of 30 HP., working at 40 lbs. pressure, and with that vessel as many as ten barges had been frequently towed at a time from London to

Richmond and Teddington, where three or four were left, and six were carried on as far as Oxford. The next boat built was of the same character, with engines of 40 HP., and that constantly towed three, four, and six barges against the stream, which ran about 3 miles per hour. Those steamers were worked profitably for four years, until the whole of the traffic disappeared from the Thames, and went to the Great Western Railway. The cost was $\frac{1}{10}$th of a penny per ton per mile. He thought the use of the screw was not possible in that case, on account of the depth of the water. The slip was rather great, more especially where the river was narrow. Taken as a whole, those boats succeeded admirably, and nothing but the discontinuance of the traffic on the river would have caused them to stop running. When it was found that the traffic was likely to cease, the boats were sold to the Commissioners of the River Severn; one was lost on the passage, but the other was still at work. For shallow rivers, where there was a considerable breadth of stream without much depth, paddle wheels were perhaps the best; but where there was sufficient depth, the screw would create less disturbance of the water. Immense opposition was experienced in introducing those boats. Probably one of the greatest obstacles to the development of steam power on canals was the smallness of the locks, which generally admitted of only two barges being locked at one time; but in the instance he had referred to this was overcome.

Mr. Leader Williams, jun., said, he was now engaged in the construction of works on the River Weaver—interfering with those of Telford and Cubitt—with a view of bringing steam power to bear. In consequence of railway competition in the conveyance of about a million tons of salt per annum, independent of the coals required for its manufacture, he recommended the trustees to remodel the river, so as to render it navigable by large vessels, and to introduce steam tugging to its full extent. The Gloucester and Berkeley Canal was a favourable instance of what might be done with steam, and it was satisfactory to hear that, along a length of 16 miles without locks, vessels could be conveyed at such low rates as $\frac{1}{12}$th to $\frac{1}{16}$th of a penny per ton per mile, especially when it was considered that there was no iron permanent way to be kept in order. On the Weaver a length of 24 miles was divided into eight pounds, some as much as 6 miles, and others only half that distance, apart. A few years ago the traders introduced steam tugs, but without success. He had just finished duplicating the locks, which were now 100 feet long by 23 feet wide, and capable of admitting vessels of 8 feet draught and carrying 150 tons. It was found that even with double locks, the delay with steam tugs towing several barges was so serious, and so interfered with the traffic, that that plan had to be given up. About two years ago, steam barges conveying their own cargoes were tried, and were so successful that others had been introduced. These were 85 feet long, 19 feet 6 inches beam, drawing about 7 feet 6 inches water, and carrying from 180 tons to 200 tons in each. It was found, with direct-acting engines of 20 HP., that there was no difficulty in towing two or three lighters carrying 100 tons each, behind the barge; but then, of course, there was delay at the locks. It was clear if that difficulty could be removed the traffic would pay well; and the trustees had obtained an Act for raising £200,000 for the improvement of the navigation. A third lock was about to be made for each pound. This lock was to be 200 feet long and 40 feet wide, and it would enable each tug to take three barges through each lock. In this way not only would the disadvantages of ordinary locks be overcome, but a positive gain would be effected by taking four vessels through instead of only one. It would be a canalised river, partly river navigation and partly a long canal. The top water minimum width, which at present was about 60 feet, was to be increased to 90 feet, while at the bottom the width would be 54 feet, with a depth of 12 feet. That section, compared with the Gloucester and Berkeley Canal, would give great advantages. The character of the soil was better, and he believed the work would be carried out with slopes of 1½ to 1. It was hoped by these measures, not only to have steam barges, but coasting vessels up to Northwich. He could not give the cost per ton per mile, as the traffic was in the hands of the traders. On the Weaver sailing vessels and hauling by horses were being abandoned, and the steam barges he had alluded to were considered to be most profitable.

Mr. Hubert Thomas said, through the Secretary, that the engine boat 'Dart,' the property of the Grand Junction Canal Company, was built of timber, and was 70 feet in length, 7 feet beam, and drew, when loaded, about 4 feet. The length occupied by the engine cabins and decks was 31 feet, leaving for the stowage of goods 39 lineal feet. The distance travelled between 1st October, 1864, and 1st October, 1865, was 11,280 miles; the number of tons carried and hauled was 3,182; the working expense, including the engine and accompanying boat, was £366 13*s*., which was equal to 7·8 pence per train mile, and ·184 of a penny per ton per mile of cargo conveyed.

The vessel was fitted with an 8 HP. steam engine, and a Griffiths' three-bladed screw propeller of 3 feet diameter. The engine was constructed at the Company's works, under the superintendence of, and according to designs prepared by, Mr. Elliott. The cylinder of the engine was 9 inches in diameter, with a length of stroke of 8 inches, and was worked expansively, with the steam cut off at half-stroke. The pressure in the boiler was 75 lbs., and the speed 180 revolutions per minute. The cylinder was vertical, and acted directly upon the shaft of the propeller. The connection of the engine with the shaft was so arranged, that in the event of any uneven wearing of the bearings no undue strain was brought on the engine, which considerably lessened the risk of accident from that cause. To pump the bilge water from the engine room, and for feeding the boiler with water, a small compact donkey engine was fixed to the side of the boat, in the engine cabin, and had a double action, one for feeding the boiler, the other for pumping the water from the vessel in case of need. This engine could be worked with a pressure of steam in the boiler of 5 lbs. To it also was attached a water-heater, in which the temperature of the water was raised to about 200° before it passed into the boiler, thus effecting a great saving in the consumption of fuel, and producing an even working pressure. The vertical flue boiler attached to the engine was of the following dimensions:—Height 7 feet, diameter 4 feet 3 inches, diameter of fire-box 2 feet 10 inches, and 2 feet 10 inches from the fire-bars to the crown of the fire-box; the depth of the flue being 3 feet 4 inches, and the width 3 inches, and the water spaces 2 inches. The internal flue, or chimney, was 4 feet in length by 9 inches in diameter. The area of the fire-bar surface was 5 feet, with an effective heating surface of 120 feet. The shell of the boiler was constructed of the best Staffordshire plates $\frac{3}{8}$ of an inch in thickness, and the whole of the interior of the boiler was constructed of Low Moor plates also $\frac{3}{8}$ of an inch in thickness. The boiler, before being placed in the boat, was tested with a pressure of 150 lbs. to the square inch. The exhaust steam was rendered serviceable, in preventing the emission of smoke from the chimney, by an arrangement of pipes, fitted with a valve, the pipes passing into the funnel of the boiler. The result was that no smoke was allowed to escape, which was very desirable when passing through long tunnels.

Mr. W. H. Bartholomew said, through the Secretary, that steam haulage was introduced on the Aire and Calder Navigation so far back as the year 1836. It was conducted by means of paddle tugs, having high-pressure engines; the cylinders, two in number, were 11 inches in diameter, and had a length of stroke of 20 inches. The paddle wheels were $9\frac{1}{2}$ feet in diameter by 3 feet 6 inches wide. Internal flue boilers were used, working at a pressure of from 50 lbs. to 60 lbs. per square inch. The cost per boat per mile hauled was 8·516 pence, and per ton per mile ·473 of a penny. The speed with three boats, containing 100 tons of cargo, was 3 miles per hour in the canals, and 4 miles in the rivers.

The employment of steam power on the Aire and Calder was confined to the main line between Leeds, Wakefield, and Goole—a distance of 36 miles. Between Leeds and Goole there were ten locks, having a total fall of 66 feet, and between Wakefield and that port there were seven locks, with a total fall of 50 feet. Between Goole and Castleford the locks occurred at intervals of 9 miles, and above that place at intervals of about 2 miles. The depth of the canals was 8 feet 6 inches, and of the rivers 9 feet to 10 feet. The top width of the canals was 60 feet to 66 feet, that of the rivers 100 feet to 150 feet. The bottom width of the canals was 30 feet, the sides having slopes of 2 to 1; the average sectional area was 380 square feet. Improved means of steam haulage were introduced in the year 1853, which had been continued and extended to the present time. The method of propulsion was the screw. Two systems of employing it were adopted, viz., that of the tug carrying cargo, in addition to its tugging capabilities, and that of the tug having increased power, acting solely as a tug. The first-mentioned class of tug was confined to the merchandise traffic. The dimensions of these tugs were—length, 63 feet 6 inches; beam, 12 feet 6 inches; depth, 7 feet 6 inches; capacity for cargo, 30 tons. The machinery occupied 20 feet in length of the after part of the vessel. The engines were high pressure, direct acting, on the inverted diagonal arrangement. The cylinders were 8½ inches in diameter, and had a length of stroke of 12 inches. The boilers were tubular, fitted with copper fire-boxes and brass tubes. They had 12 square feet of grate surface, 26 square feet of fire-box, and 217 square feet of tube surface; the working pressure was 100 lbs. per square inch. The propeller was 5 feet 3 inches in diameter, and 7 feet pitch, making about 180 revolutions per minute. The average cost of haulage by steam tugs for the past seven years had been 2·125 pence per boat per mile, and generally ·085 of a penny per ton per mile. This traffic was conducted during the night, at an average speed of 4·5 miles per hour, at which speed the canal banks sustained no injury.

The second class of tug was solely employed for towing the general traffic. The dimensions of the vessel were similar to those described for the merchandise traffic. The machinery occupied the whole of the vessel, except so much as was set apart for the crew. Its arrangement was different to that previously described. The engines were direct acting. The cylinders were inverted, and placed overhead. Their diameter varied from 15 inches to 18 inches, and the length of the stroke from 12 inches to 16 inches, and the working pressure was from 60 lbs. to 80 lbs. These tugs were fitted with two propellers, on the same shaft, 6 feet in diameter, set some distance apart, and at right angles to each other. The leading propeller had a pitch of 7 feet 6 inches, and the after one of 8 feet 6 inches. The boilers were return tubular, with two fire-boxes, having the tubes beneath the latter, and had, for the cylinders of 16 inches in diameter, 16½ square feet of grate surface, 116 square feet of fire-box, and 804 square feet of tube surface. They would tow ten keels, having 700 tons of cargo, at 3 miles per hour in the canal, and 4 miles per hour in the river. The charge for towing was at the rate of $\frac{1}{10}$ of a penny per ton per mile against the stream, and $\frac{1}{12}$ of a penny per ton per mile down stream.

Two vessels fitted with steam power, and capable of carrying 160 tons each, had been recently set to work; but the short time they had been in operation did not justify more than a passing notice. A new mode of carrying minerals had been lately introduced by Mr. Bartholomew. It consisted of a train, composed of seven rectangular boats, having their ends constructed with an outward curvature of 6 inches. The dimensions of the boats were, length, 20 feet, beam varying from 15 feet to 16 feet, and depth, 7 feet 3 inches. Each compartment, or boat, was capable of containing from 25 tons to 35 tons. When formed into a train, they retained their lateral position by means of a projecting stem, which fitted into a corresponding hollow stern-post. They were held together and steered by wire ropes, which passed through suitable guides on each side, and which extended from the steam compartment at the after end to the leading or stem portion at the other. They were tightened by hydraulic power, and when together formed a train, or vessel, 190 feet in length. They were steered by two steam cylinders, having their pistons in direct connection with the wire ropes, and were found to answer well in all respects. Each compartment was fitted with spring buffers at its corners. The compartments were discharged by hydraulic power, which raised the compartment and its cargo, weighing about 42 tons, to the elevation required to suit the height of the ship. At this stage of the operation the compartment was gradually turned on its side, and the contents discharged into a large shoot, and thence into the ship. In this way 100 tons to 120 tons per hour had been shipped; but this quantity was entirely ruled by the sizes of the ships' hatchways and the number of trimmers.

Mr. R. P. Brereton said, he could not gather from Mr. Healy's Paper why the particular form of screw adopted was considered the best. It was stated that preference was given to a width of blade of 32 inches, with a sharp taper; but whether that preference was on account of towing purposes, or as regarded the disturbance of the bottom of the Canal, did not appear. In the first Paper the damage to the canal banks was attributed to the action of the paddle wheels; and it was remarked that this action was confined to a width of about 18 inches along the banks, partly above and partly below the water line. He was anxious to ascertain whether, after a lengthened employment of the screw propeller on these navigations, there had been any opportunity of examining the condition of the bottom of the Canal, and also what the bottom consisted of.

He was led to ask for that information owing to a circumstance which happened to the 'Great Eastern,' from working her screw in shoal water. She was placed upon the gridiron at Liverpool, and her screw was worked to back her off it and move her astern. After several revolutions of the screw, the ship started, but she had not proceeded above 80 yards, on the incline of the gridiron, before she pulled up and grounded so as to lose the tide. On inquiring into the cause, it was found that the blades of the screw had cut a hole in the sandstone rock about a yard in depth, which ultimately stopped her. That being the case, he could scarcely imagine but that considerable disturbance to the soft bottoms of canals was occasioned by the action of the screw, at whatever speed it might be worked; and upon that point, as well as the nature of the bottom, he should be glad to receive some information.

Mr. Michael Scott said, in estimating the cost of propulsion, regard must be had to the relation between the size of the vessel and the dimensions of the water-way. In the case of a vessel passing through the water at a given velocity, the resistance would be less in a large water-way than in a small one. In other words, a vessel which would create considerable disturbance in a narrow canal, would pass through a large channel without creating any appreciable wave. Another point which occurred to him was, that the eroding power of the wave would be greater upon an extended slope of bank than upon a vertical face.

Mr. J. F. Bateman remarked, that on the Aire and Calder Canal the screw propeller had been worked since 1853. A few years ago he made an examination of the banks of that Canal, and up to that time no mischief had been done. The average depth of water was upwards of 6 feet. The precise draught of the vessels, in proportion to the depth of water in the Canal, he did not remember; but he knew there was considerable space between the bottoms of the vessels and the bottom of the Canal. He might mention that, on the Forth and Clyde Canal, some years ago, before the introduction of steam tugs, a very convenient class of canal boat, capable of carrying 80 tons of cargo, and of being drawn by one horse at a rate of 3 miles an hour, was employed. The cost of haulage was then about $\frac{1}{12}$th of a penny per ton per mile; but in that case the Canal was 9 feet 6 inches in depth, and the draught of the boats was 5 feet 6 inches to 6 feet, leaving upwards of 3 feet between the bottom of the boat and the bottom of the Canal. Being a ship canal, of great width, the water had free means of escaping by the sides, as well as below, so that no surge was created, as was the case in narrow canals. That was a matter to be regarded in the question of haulage upon canals.

Mr. Robert Mallet remarked, that he was concerned, a quarter of a century ago, in some rather large experiments on the Irish canals, of which no account had as yet appeared. As the results obtained were, in some respects, remarkable, he would state that, about the year 1836, Mr. Hunter introduced on the Scottish canals, fly boats capable of carrying sixty passengers, when towed by two horses. About two years after, Mr. Mallet was instrumental in getting that description of boat adopted upon both the Grand and the Royal Irish Canals. They carried sixty passengers at the rate of about 8 miles an hour, were towed by two horses, and occasionally by three. The distress to the horses was, however, considerable, owing to the wave of translation, which travelled along with the boat when at full speed, passing on a-head when the boat pulled up, and so requiring to be re-established when the full speed was to be restored. The late Mr. Charles Wye Williams, and Mr. Watson (Assoc. Inst. C.E.), the present managing director of the City of Dublin Steam Packet Company—but then the manager of the inland department of that Company, comprising the Canal and Shannon Navigation, for goods on both, and for passengers also on the latter—were thus interested in improving the passenger boats on the canals in the hands of the Canal Companies, and of ascertaining how far this could be effected by the substitution of steam power for that of horses. Mr. Watson had patented a canal boat capable of parting in two in the middle, and jointed in a peculiar manner, so that the two halves could be placed parallel to each other, and so be passed through a lock of 70 feet long, although the boat when together was about 120 feet in length. The object was to get a vessel of the smallest beam and the smallest transverse section of displacement, so as to offer the least resistance in the narrow waters of the canals. The proposal was then laid before Mr. Mallet, to adapt steam power and paddle wheels to this boat, in place of horse power. The aim, of course, was to pack into a vessel of that kind, so narrow in beam and crank, the greatest power that she was capable of containing, and to apply it so as to obtain the highest speed possible. The conditions of the problem were, that if a speed of about 8 miles an hour could be obtained, with a cargo of sixty passengers and their luggage, so that the journey from Dublin to Shannon Harbour could be made in one day, it would be a success; and it was believed it would then answer commercially. The boat was of such extremely small beam —5 feet 9 inches—so crank and so flimsy in build, that there was great difficulty in putting adequate power into her, or in obtaining sufficient foothold for machinery in a boat of such length, built of half-inch oak planking. He designed for this boat high-pressure engines capable of being wrought up to about 40 HP., with a boiler on the locomotive plan. The weights were distributed, by the aid of longitudinal trussed keelsons, over as large a floor as possible, to enable the boat to sustain them. The entire weight of engines and boiler in working trim did not exceed 5 tons—screw propulsion, it would be remembered, was then unknown. The diameter of the paddle wheels was much limited by the height of the bridges to be passed under, and the width of the floats by the narrowness of the locks. The form of paddle floats he adopted was that proposed by the late Mr. George Rennie, which were then believed to possess some peculiar properties in going easily into the water and lifting very little of it. Each float was of the shape of the section of an egg, dipping point down. Various different shaped and sized paddle floats were afterwards applied to the same engines, with slightly different radii of paddle arms, and different dips, and with varying, and in some cases apparently anomalous, results. With a load equivalent to sixty passengers and their baggage, a maximum speed of 7·08 miles an hour was attained, with the original oval float boards, 24 inches deep and 17 inches wide, and with the engines working considerably below their full speed. Several curious and anomalous facts were observed. The boat was tried upon both canals—one with a section of 40 feet and the other of 44 feet water surface—flat bottom of 25 feet, sides sloping about $1\frac{1}{2}$ to 1, and mid-depth 6 feet to $6\frac{1}{2}$ feet of water. When the boat was put in motion the speed was rapidly brought up on either canal, without notable disturbance, to 6 miles an hour. A wave was then produced, the crest of which crossed the canal close in front of the boat, which never rode upon it or over it. It was not a wave of translation, for the speed of such a wave, due to the depth, 6 feet to $6\frac{1}{2}$ feet, of these canals, was about 8 miles an hour, which the boat never reached. Although 7 miles an hour was the speed with about half the power of the engines, when they were worked up to full power, the result was a tremendous surge at the sides and rear of the boat, but no distinct increase of speed. In fact, a better result was obtained with 32 strokes per minute than with the maximum of 55; the only effect of the additional number of strokes being to create violent disturbance of the water in the boat's wake. At the bridges, where the Canal suddenly narrowed to the width of the locks, or to 14 feet, and where the greatest amount of resistance might have been expected, the engines (for the second or two while the paddles were passing the spot) flew away, showing that the back current of the water, required to fill the comparative void in the wake of the boat, took away the fulcrum from the paddle wheels, and was one of the causes of defective speed. There was a peculiarity in the form of the after or following wave that was created by the action of the paddles and passage of the boat. It went off at an angle of 30°, from the tail of each paddle wheel towards the bank, and was there reflected sometimes as many as five or six times after the boat, producing a set of waves crossing in a lattice form; but there was no disturbance ahead beyond a simple roll or pushed-up wave of about 9 inches, as already referred to. One curious experiment was made by attaching three picked and powerful fast post horses to the steam-boat, capable of keeping a strong strain upon the tow line while the engines were at work. On one occasion he started the engines and four horses at the same time, when the speed of the boat was rapidly brought up to 10 miles an hour, and that rate was maintained for perhaps 300 yards or 400 yards, the engines flying away and the horses being scarcely able to make speed enough to keep the tow lines taut. The true wave of translation was now soon produced, upon which the boat for a short time rode. This increased in magnitude, and very soon brought down the speed of the boat to its own rate, or to 8 miles an hour. Throwing off the horses when the speed was highest, it was almost immediately reduced to about 5 miles an hour, and until the water got tranquil could not be restored. Mr. Charles Wye Williams, who, as was well known, was the patentee, in an early stage of steam navigation, of a peculiar form of paddle wheel with feathering floats, the floats being of the oar shape, passing deeply into the water edgeways, and coming out also edgeways, was anxious that this form of paddle should be tried, and a pair of paddle wheels of that form was fitted to the same engine and boat. The result, as Mr. Mallet anticipated, showed no improvement in speed; but in place of the after surge taking the form it did with the fixed float boards, as previously described, the surge was now right across the canal, not far off the stern, and it followed the boat in a continuously breaking wave. In conclusion, he would remark, that it was quite certain from what was now known—thanks to Mr. Scott Russell and others—of the nature and laws of production and motion of waves of translation, that the height of the wave above the fluid service of repose measured about the depth of the water disturbed by the wave below the normal water level. The height of this wave in these canals never exceeded 9 inches at the speed of 7 miles per hour; but with a speed of 8 miles an hour no doubt there would be produced as much or possibly more surge than that of the fly boats—viz., from 15 inches to 18 inches. It followed then, that the depth of the water disturbed by the wave, or the depth to which its disturbance could have any sensible effect in injuring the banks, could not be more than from about 2 feet to 3 feet. From this it resulted, that if the shallow water at the edges of canals, of the section above described, was cut off by vertical walls, of whatever construction might prove cheapest, so as to have a depth of about 4 feet of water at the wall, at either side of the canal, no surge of the dimensions and character above described could do any injury to the bottom or channel of the canal. To meet the scour due to the rush backwards of water to fill the wake of the boat, the total transverse section of the canal must be relatively large to the immersed cross section of the boat. The angle of the slopes of the Irish canals was originally that due to from 2 to 1 to $1\frac{1}{2}$ to 1, but by the action of the water and of time, the sloping sides had become irregularly curved into a rolling batter.

Mr. Abernethy observed, that the canals which had been alluded to were not originally designed for steam traction, but merely for horse haulage. The consequence had been, in some cases, even where steam power had not been employed, but the sectional area of the boats had been enlarged, an increased height of wave and greater destructive action upon the banks. In other cases, where the section of the boats had not been increased, but steam power had been applied to propel them at a greater velocity than by horse power, the same results had taken place. There was not at present, so far as he was aware, a single instance of a canal specially adapted for the application of steam power; and it was desirable that a Paper should be prepared on that subject, describing the best form of canal for the purpose, having regard to the due proportions between the sectional area of the canal and that of the boats, together with the form of bank which would best resist the action of the waves, and the arrangement of locks to enable a train of boats to pass in and out with facility. He was struck with the result of the action of the wave in this case, which seemed to show that the slope should have a rolling or curved batter. He was some years ago engaged on the Aire and Calder Navigation for the late Mr. George Leather. As it had been stated that the banks of that canal only suffered slightly from the waves caused by steam haulage, it might be interesting to notice that the section on which he was employed, from Wakefield to Lake Lock, had a width at the top of 74 feet, and at the bottom of 31 feet, with a depth of water of 7 feet 3 inches. There were dwarf retaining walls at the sides, having a depth of $1\frac{1}{2}$ foot of water against them, and then a slope of 2 to 1, with a rolling or curved batter.

Mr. Mallet wished to supplement one fact he had omitted. The same boat to which he had alluded was, at the suggestion of Mr. Wye Williams, brought upon the comparatively open waters of the Liffey, at the port of Dublin, where she attained an estimated speed of about 10 miles an hour, whereas that on the canals never exceeded 7·08 miles.

Mr. Vignoles remarked, that the principle enunciated by Mr. Mallet, as deduced from theory, as to a nearly vertical retaining wall of a certain depth at each side, was no doubt that of the method best calculated to resist the action of the water upon the banks of a canal.

Mr. Mallet said, what he meant to convey was, that the disturbance produced by a wave of translation raised by a solid body passing through a canal would not extend sensibly deeper in the water of the canal than the height of the wave over the canal when at rest. If, therefore, the banks were protected down to that depth, nothing below it would be seriously affected by the scour or disturbance produced by such a wave.

Mr. Vignoles apprehended that was an inference drawn from theory, not from practice, but it was no doubt correct. As the result of Mr. Mallet's observations, he recommended that form of section. Mr. Abernethy had shown that a retaining wall had been successfully applied, under certain circumstances, to a depth of 18 inches. Following out that principle, if the depth were increased to 3 feet, with that form of canal, although the cost would be somewhat greater, yet the beneficial results, on the larger canals, where steam was likely to be employed, would, he believed, justify the adoption of such a step.

Mr. F. J. Bramwell remarked, that in the first Paper it was stated that one of the engines employed had a cylinder of 20 inches diameter, and a length of stroke of 18 inches, with 32 lbs. pressure of steam: and that another engine had a cylinder 16 inches in diameter, and a length of stroke of 18 inches, with only 25 lbs. pressure. He gathered that in both instances these engines were non-condensing. He wished to enter his protest against the employment of such implements as non-condensing engines working at 32 lbs. and 25 lbs. of steam. Many people undertook to make steam engines, and many allowed them to be used, who did not consider that when non-condensing engines were employed, the steam had to be raised to the pressure of the atmosphere before any work could be done, and then it had to be raised further to do the work; and that the smaller this further raising, the greater was the percentage which the atmospheric pressure (representing loss) bore to the whole. With non-condensing engines working 25 lbs. and 32 lbs. steam, the pressure of the atmosphere was from three-eighths to about one-third of the pressure producing work. The cylinders of non-condensing engines should be of such dimensions, and the expansion employed should be of such an amount, that at least 60 lbs. to 80 lbs. pressure of steam should be used, or, better still, 120 lbs., and then the original atmospheric pressure became reduced to one-fourth, one-fifth, or one-eighth of the pressure doing the work. He felt compelled to apologize for speaking on a matter so well known; but he did not like to let the statement in the Paper pass without an expression of opinion as to the impropriety of the practice.

Mr. E. A. Cowper said, in reference to the haulage of boats on canals, that he had had opportunities of observing the action of water in canals on the passing of steamboats at various velocities, particularly Ericsson's experiments with different propellers, and on the Birmingham Canal Navigation with screw propellers. He believed that, for good speeds, it was inadmissible to throw off large quantities of water from the bows, to form heavy waves against the banks. He was convinced that some better plan of passing the water by the boat, would be the best means of getting the boat through the water at a fair speed, and without washing the banks unnecessarily. If a canal was only of moderate section and depth, and the section of an ordinary boat passing through it was large in proportion to that of the canal, the water displaced from the front of the boat must flow along the canal in a contrary direction to that of the boat, and thus pass along between the boat and the sides of the canal. The consequence was a considerable rush of water past the boat, and as the boat had to travel through water passing backwards, it really was going through the water at a greater speed than its rate of progress. On one occasion he had noticed that, as the steamboat was passing through a canal, the water began to rise, or 'bank up,' fully 100 feet ahead of it (as could be seen by the reflection of the light on the water); and the water being thus caused to rise by the pressure of the bows, there was formed a head of water in front of the boat, which, as it escaped from the bows, rushed past the sides and made a very considerable wash, particularly just astern of the boat, where the water was flowing into the hole left by the boat. It appeared to him, therefore, that if a hole could be dug, as it were, in front of the boat, or the water be taken away so as to keep it down to the exact level of the canal, and be put in behind the boat, there would be less obstruction to the passage of the boat than by forcing the water sideways, and obliging it to run very fast past the boat. An experiment was tried with two boats, one of which was being towed by a horse alongside the other, which was a steamboat, and it was found that the steamboat could not pass the other boat, because the propeller made a hole in the water in front, and banked it up behind, thus helping it forward. If the Ruthven, or other propeller, acting by the emission of water, were adopted, the water ought to be taken from the bows of the boat, passed through the boat by a pipe, and be ejected at the stern, thus making a hole in the water in front of the bows, or at all events preventing any resisting head of water being formed in front, and at the same time filling in the hole formed in the water by the passage of the boat, or at least preventing there being any diminution in the head of water pressing against the stern of the boat. If the water were taken through a pipe equal to the section of the boat, there would be no disturbance of the water; but as a pipe of that size could not, of course, be adopted, one of much smaller section might be used, as the water might very well pass through it at a much higher speed; indeed a high speed was necessary in any case with an emission propeller, in order to overcome the friction of the boat through the water. Probably it would be best to take the water in at the bows through perforations, so as to distribute the draught of water over the surface, which would otherwise, or under ordinary circumstances, exert a pressure against the water; or it might be found advisable to make a kind of funnel of the head of the boat for the entrance of the water to the pipe. The emission of the water at the stern might likewise be through a number of perforations, or through a single pipe, more or less tapered. It was probable that a screw propeller, or Appold's pump, would answer the purpose of drawing in water through the pipe and throwing it out again. Of course he was aware that there would thus be some sacrifice in tonnage, but the object to be obtained, viz., a good speed with steamboats on canals, or restricted channels, without injury to the banks, was of such vital importance to canal companies, that it would be well worth some rearrangement of cargo in order to attain it.

Mr. Beardmore said, some of the remarks he might have offered had been anticipated. Steam navigation on the smaller inland canals was full of difficulties. The question was, how to get the largest carrying capacity with the least sacrifice of space in the vessel, adapting thereto steam-propelling power, with fair speed? As a rule, the inland canals in this country might be taken as having a width at the top of about 45 feet, and a depth not exceeding 5 feet, though generally not more than 4 feet, with a vast number of locks on their course, frequently only admitting boats 7 feet 6 inches in width and 70 feet in length. If anything like trains with steam tugs were attempted, the loss of time in passing each vessel separately through the locks was so great as practically to prevent the successful adoption of that mode of transit. From this delay, and the difficulties offered by resistance in the restricted water-way, all attempts to work by steam trains on the canals of this country had failed. Steam trains had been tried, on an extensive scale, on the Shropshire Union Canal, with sufficient capital at command; but the experiment was a failure, from the difficulties encountered in passing the locks, and getting through the shoal-water sections of the canal. The same causes had operated against the success of steam-towing on the Kennet and Avon, the Leeds and Liverpool, and many other canals. The Grand Junction Canal Company alone still worked a portion of their traffic by steam traction. He had prepared a diagram (Plate 1, Fig. 1) to show the difficulties of getting a vessel to move through the water when there was a restricted area of channel, and why it was necessary to have ample depth and width of water-way, if steam power were to be applied successfully in a commercial point of view. The difficulties arose from a strong backward current that must pass between the vessel and the banks, and which operated in retarding the vessel, from the form of the vessel necessary for giving carrying capacity, and from the close approximation of its bottom to the bed of the canal preventing a proper supply or 'feed' of water to the screw; and this varied with the velocity, diameter, and pitch of the screw, and with the form and relative proportion of the diameter of the screw and the sections of the vessel and of the canal. To give some idea of the difference of speed where there was a sufficient water-way, and the contrary, he might state that in running with one of these small steamers in a narrow part of a canal, if an open part, or a ballast hole, were suddenly reached, the steamer would shoot a-head so as to throw down a person standing carelessly: this had occurred to himself from the steamer passing over a ballast hole.

The sections, Nos. 1 to 5, Fig. 1, Plate 1, showed the proportions of various river navigations and inland canals. The smaller class of canals had a water-way of about 108 feet of sectional area, and when the midship section of the boat was 20 feet, the proportion between the two was 5·4 to 1; some larger canals had 150 feet of sectional area, so that with the same midship section of boat, the proportion was as 7·5 to 1. On the smaller sections steam power must work at great disadvantage. Figs. 2, 3, and 4, Plate 1, showed the elevations, sections, and plans of a steamer now in daily use on the River Lee. The width of the beam was 13 feet, with from 3 feet to 4 feet draught. On some sections of the navigation its speed was not more than $2\frac{1}{2}$ miles per hour; indeed he had known it to be as low as $1\frac{1}{2}$ mile, while in more extended sections, the speed would be 4 miles to $4\frac{1}{2}$ miles per hour, and with less consumption of fuel than when the speed was only 2 miles an hour. In steam navigation on canals, in addition to the difficulties of restricted section, there were the locks, which governed the size of the boats and their capacity for freight. The problem was how to drive an almost rectangular box through the water. In the section exhibited, besides a slight point to the bows, and a limited run to the stern, the angles where the sides joined the floors (technically called the 'chines') were rounded so as to enable the water to reach the screw more readily. This would give a practical exemplification of the difficulties encountered in applying steam for the carriage of freight. He had advised the trustees of the River Lee, to build a steam barge adapted to the general trade of that navigation, to suit as a model, and to show how economically work could be thus performed. Mr. Milne, of Glasgow, assisted him, and a vessel was built 13 feet wide, and so that the draught should not exceed 4 feet. To obtain a better run for the vessel, and to allow the water to pass easily to the screw, the barge was made with circular chines, in this respect differing from the ordinary barges on this river, which had square chines. The result was to take off at the same draught about 10 tons of carrying capacity, including the weight of the engines (about 3 tons), when compared with the usual barge freights. Thus traders had reason to complain, that only 500 quarters of malt, &c., could be carried, while with the old barges 600 quarters could be taken. The preference on the Lee navigation remained at present with the old system; and considering that an ordinary horse could tow 60 tons to 70 tons of freight a distance of 27 miles in fourteen hours, and that the crew consisted of only a skipper and one man, besides the horse-boy, there was little margin for economy. The entire expenses of taking cargo to London in this way amounted probably to one halfpenny per ton per mile.

At present, however, this navigation laboured under the disadvantage of having 8 miles of its length of the small section, No. 3, Fig. 1, Plate 1, carrying only 4 feet of water on the old lock cills. When this portion of the navigation was completed to the section No. 2, which with portions of No. 1 section formed about 19 miles of the River, it would be practicable to apply screws of 5 feet in diameter, and cargoes of 90 tons to 100 tons might be conveyed. The steam barge in question could run from Hertford, or Ware, to London with from 55 tons to 60 tons of cargo, and return with a freight —the whole distance being from 65 miles to 70 miles, including from 10 to 15 miles on the Thames—with a consumption of about one ton of coals, and at a total expense, including wages of the men, depreciation for wear and tear, and interest on capital, of one-third of a penny per ton per mile. On the larger section the speed was over 4 miles an hour; on the narrower section, including the stoppages at the locks, the speed was not more than 3 miles an hour.

In Mr. Bartholomew's communication, it was stated that the average cost of haulage by steam tugs had been 2·125 pence per boat per mile, or ·085 of a penny per ton per mile, where several barges were taken by one steamer, many of which carried 90 tons. On the River Lee one-third of a penny per ton per mile embraced every expense of a steam barge carrying her own cargo alone. While in the case of the Grand Junction Canal steamer, the expense was 7·8 pence per train per mile, and ·184 of a penny per ton per mile of cargo conveyed. The difference he attributed chiefly to the limited section of that Canal, as shown by section No. 5, Fig. 1, Plate 1, the steamer not carrying more than 20 tons of freight, and hauling about 28 tons besides. Engines with a detached boiler, and one vertical cylinder only, were used on the Grand Junction Canal; in other respects they were similar to those described by Mr. Appleby in Figs. 4 and 5, Plate 2.

From these examples, and others which have been cited, it would be seen that the cost of working depended to a great extent on the section of the Canal, as this governed the speed of the vessel. In some cases there were greater facilities for steam tugging than in others. On the Regent's Canal there was a 2-mile level at the head of the canal, on which portion alone steam had been applied; on this head-level there were two tunnels without towing-paths, and when the tug-boat was not used the vessels had to be 'legged' through those tunnels—an operation still carried on to a great extent in this country, although causing delay in transit. On the Lee he put a towing-path wall by the side of the River, wherever practicable, and this converted section No. 3, Fig. 1, Plate 1, into section No. 2, Fig. 1, Plate 1. By this a depth of from 3 feet to 4 feet of water was brought up to the wall, and from 8 feet to 10 feet of width was added to the water-way. In the altered section the same steamer with the same power would run at least $\frac{3}{4}$ of a mile per hour faster. This plan afforded great facilities for craft passing on the River; and enough space could generally be got out of the old towing-path and slopes, to obtain the additional breadth of canal, and yet leave 8 feet to 10 feet of path. The depth of the wall was from 5 feet to 6 feet; it was carried out in lengths of from 40 feet to 60 feet at a time, and with care no more water percolated to the foundations than could be commanded by a hand-pump. Some miles of the Lee had been treated in that way, with great advantage in the after maintenance, as well as from the additional room afforded. At the tidal entrance of the Lee Navigation, near the Thames, at Limehouse, he had recently built walls in the same way from 14 feet to 16 feet deep; and in carrying out the work he had no better dam than was afforded by driving temporary piles 6 feet or 8 feet apart, and camp-sheeting within them. The old facing assisted to form the dam; behind which the trench was sunk, with close runners, 11 inches by 3 inches, and the material excavated was thrown out in front. The wall was then built in the trench with Kentish rag-stone set in Portland cement concrete for the face, the backing being in blue lias lime. The section of the wall was 5 feet at the base, and 2 feet 6 inches at the top. After the walls were built, the temporary piles and planks were removed, and the excavation dredged. The whole work cost about thirty shillings per lineal foot.

The engines in the steamer to which he had alluded were from the model of Mr. Milne, and were admirably designed. The vessel had been applied to every kind of use for five years, both for freight work and as a lighter for earth and stone work, being frequently grounded every tide in the Thames, yet neither engines nor boilers had cost sixpence in repairs. He thought it might perhaps be better to allow 12 inches more length in the engine room, to give the driver elbow room, and rather more coal bunker. This reduction of the cargo space would not practically reduce the freight. The details of the engines and the form of the steam barge in question were shown in Figs. 2, 3, 4, 5, and 6, Plate 1. The length of the barge was 78 feet, of which 7 feet were occupied by the engine; the depth was 5 feet at the centre, and 5 feet 9 inches at the ends, with $2\frac{1}{2}$ inches additional of keel; breadth, 13 feet 2 inches; thickness of iron plates, $\frac{1}{4}$ inch, with ribs $2\frac{1}{2}$ inches by $2\frac{1}{2}$ inches by $\frac{5}{16}$ of an inch; internal diameter of boiler, 3 feet; height, 6 feet 4 inches; thickness of boiler plates, $\frac{3}{8}$ of an inch. There were fifty-five tubes 2 feet 6 inches in length, tapering from 2 inches in diameter at the top, to $2\frac{3}{8}$ inches at the bottom. The cylinder was $5\frac{1}{2}$ inches in diameter, with a length of stroke of $9\frac{1}{2}$ inches; the diameter of the screw was 3 feet 4 inches, and the pitch about 4 feet. About one hundred and twenty revolutions per minute gave a speed of 2 miles to $2\frac{1}{2}$ miles per hour in the cuts, 3 miles to $3\frac{1}{2}$ miles per hour in the largest sections, and 4 miles to 5 miles per hour in the Thames, with a cargo of 50 tons to 60 tons, but the speed was not sensibly increased when the vessel was in ballast. The engines might be taken generally to represent those in use on the Forth and Clyde Canals, as described in Mr. Milne's communication; but the depth of that navigation admitted a much larger screw. One of the difficulties of steam navigation on small canals, where the traffic was not very continuous, resulted from weeds; they abounded between June and September. Some of these gathered round the screw, and could only be cleared by continually reversing the screw, which, with the simple form of direct engines and link motion, was done by the helmsman as readily as by the driver. The 'silk weed' was also very troublesome, from its choking the valves of the force pumps.

Mr. Bateman remarked, in corroboration of Mr. Beardmore's calculation of the cost of working by steam, that on the Forth and Clyde Canal between Bowling and Glasgow, where there was a rise of 150 feet, and a considerable number of locks, the cost of working the system of steam lighters was 0·23 of a penny per ton per mile.

Mr. Beardmore suggested, with reference to the system of cargo trains introduced by Mr. Bartholomew on the Aire and Calder Navigation, that the plan was a complete novelty, inasmuch as the train was moved like a caterpillar, being steered by strained wire ropes, leading from the stern to the head. These ropes were also the means of connecting the rectangular boxes into one flexible train driven by a stern compartment, holding a powerful driving-engine screw, and also steam pistons for steering the head of the train by the side ropes. The whole design was well worthy of a special communication from the inventor. Mr. Beardmore had accompanied one of the early trials, and it was then a perfect success, the speed being $4\frac{1}{2}$ miles an hour with a train of barges 190 feet long, and carrying 400 tons of coal; but the freights had since been considerably increased. At Goole the train was broken up, and each vessel was passed under a hoist with hydraulic gear, which lifted it above the level of the ship, and shot out the contents at one operation. This plan was more especially applicable to such freights as coals, minerals, or spoil, and the conditions of success depended on long levels, few locks, and those of great length; to the latter of which the Aire and Calder Company were now devoting considerable expenditure.

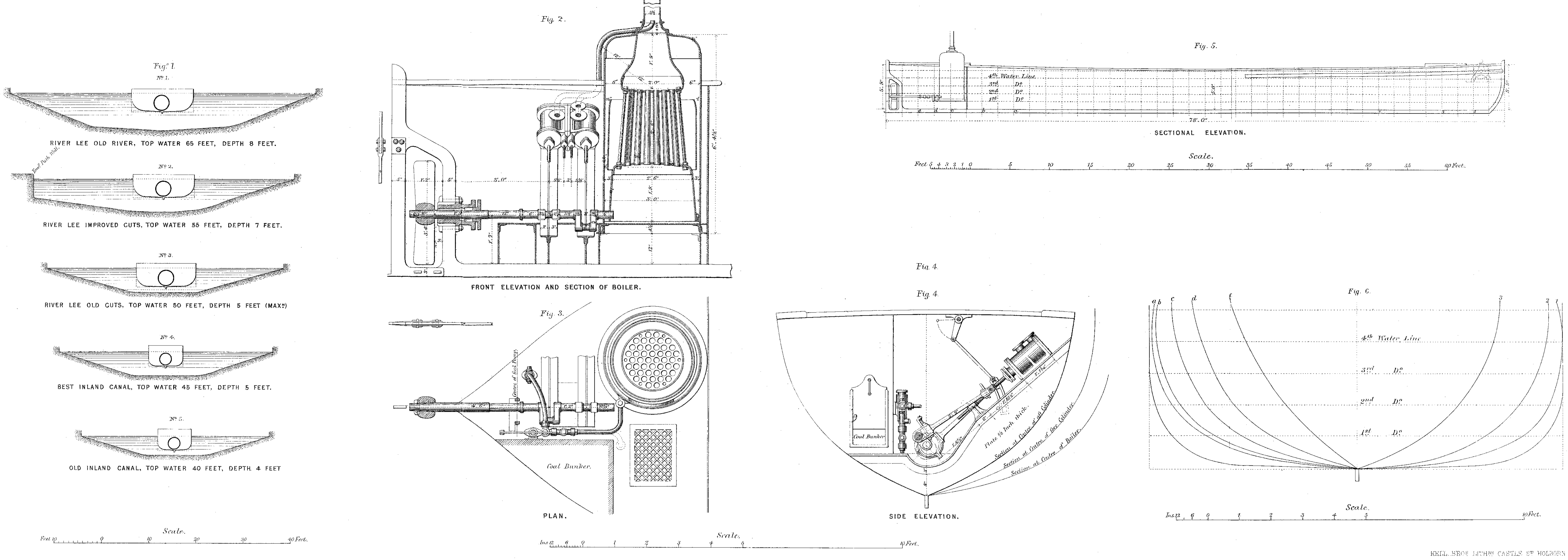
Mr. J. F. Delany described a vessel, called the 'Connector,' which was built at the Victoria Foundry, Greenwich, in the year 1858. The length was 105 feet, breadth of beam 8 feet, and depth 5 feet. She was made in three separate compartments, each compartment being 35 feet long, and forming a separate boat. These were connected together at the sides by wrought-iron pins $4\frac{1}{2}$ inches in diameter, working through hinges riveted to the sides. The several compartments could be connected and disconnected in one or two minutes. She was propelled by a high pressure 10 HP. engine and a single screw, and was employed for a considerable period in the coal trade between London and the North. The speed attained in the River was 6 knots per hour. It occurred to him that a modification of this plan might be applied to canal-boats; for there was this advantage in the system, that instead of having the wash from three vessels there would be the wash from only one bow. It also possessed considerable advantages in respect to the passing through locks, as the parts could be disconnected and connected again with the utmost facility. Another advantage was that one crew was sufficient for the whole of the train, instead of a distinct crew being necessary for each boat, and at different points along the route boats could be dropped or taken on.

Mr. C. J. Appleby remarked, that the subject of steam traffic on canals had been much studied in Holland and in Sweden, and good results had been obtained in both those countries. Having a rather intimate knowledge of the details of working in Holland, his remarks would be limited principally to that country. There, as elsewhere, the first idea was to use a small screw-propeller boat, as a substitute for towing the ordinary cargo boats by horse power, and the working results showed a great economy over the old system of haulage. But the advantage of larger boats, each carrying its own steam power, was soon seen, the principal objection to their use being, that the driver and stoker, whose wages were comparatively high, were unemployed whilst the boat was taking in and discharging cargo. This unproductive labour made a serious item in the expenses, and necessarily enhanced the cost of the water carriage, which should always be a cheap means of transit. To meet these objections, he had designed the engines shown in Figs. 4 and 5, Plate 2, in which a simple form of steam winch was combined with the propeller engine. By this combination, not only were the engineers constantly employed, but, the loading and discharging being done much more rapidly than heretofore, the earnings of the boat were sensibly increased. He believed on nearly all the lines in Holland, these propeller boats were paying well. One proprietor began with small boats 35 feet long, with engines of 6 HP. or 8 HP. of that construction. The inconvenience attending the use of these small boats had been fully discussed, and they had long been superseded by larger boats carrying their own power. The smaller boats were now used at Rotterdam for towing purposes, shifting vessels, &c., and, as moderate prices were charged for the work, they were fully employed and paid very well. Subsequently the larger boats of 80 tons to 100 tons were found too small, and perhaps now the opposite extreme had been reached by building boats to carry from 160 tons to 200 tons. These were rather large, and there was a tendency to return to boats of about 130 tons. Four boats of that capacity were being built at the present time. They were 130 feet long, 16 feet beam, and 6 feet draught of water, and carried about 160 tons of cargo. The propeller was 3 feet in diameter, with a pitch of 7 feet. The engines were 25 HP. nominal, the pressure of steam was about 55 lbs., and the number of revolutions one hundred and twenty per minute. In a great number of voyages, extending over a year and a half, between Rotterdam and Nymwegen, a distance of about 70 miles, when the traffic was good, towing a boat of 70 tons behind, these boats ran on an average $13\frac{1}{2}$ miles an hour against the stream. The voyage was generally performed in about fourteen hours, giving an average of 5 miles an hour, and the total cost, in crew's wages, coals, oil, waste, &c., was £10. 1*s.* 7*d.*, or about $\frac{1}{14}$th of a penny per ton per mile. That was exclusive of interest on the cost of the boat and repairs. Several of those boats were profitably employed in carrying forward the cargoes conveyed by the General Steam Navigation Company. By the facilities afforded by steam power, applied to the loading and discharging of the cargo, the boats could make two voyages between Rotterdam and Nymwegen per week. A great number of passenger boats were in use at the present time, and he believed they were all paying well. Most of them were owned by the skippers, who were doing better than in former times when horse traction was used. The speed was not less than 5 miles an hour, and the average speed was nearly 6 miles an hour. A suggestion had been made as to the best form of canal for steam traffic. He did not think the section proposed had been carried out in Holland, for the navigations there being much wider than was generally the case elsewhere, it was not necessary. But in Sweden, in the narrow parts the banks had been cut down in the way suggested, and at those parts it was compulsory by law to run at slow speed. Both in Holland and in Sweden, where the navigation was narrow, the speed was $3\frac{1}{2}$ miles an hour, but the general speed was about 5 miles; and with large cargoes and moderate rates, the system was paying well. From observations made in Sweden and in Holland it was evident that steam power on canals would pay: and with a moderate pitch of screw and a moderate velocity of the propeller, no appreciable damage was done to the sides of the canal, even where, as in Holland, the banks were of very soft material. In some places the slopes were pitched, but as the stone had to be brought down the Rhine, it was an expensive process, so that it was only being done by degrees. That covering was used less on account of the wash from the propellers than to protect the banks on the breaking up of frost. Mr. Beardmore had made some remarks in favour of a design of boat and engines constructed from the joint plans of himself and Mr. Milne. The boiler appeared to be multitubular, and it was stated that for a period of five years the engines required no repairs whatever. He did not know whether that remark applied to the boiler as well, because his own experience with that kind of boiler was not encouraging. He preferred straight tubes across the fire-box, with a hand-hole to clear them out, as he had never found any trouble with them; but with straight tubes in vertical boilers of that sort, he had found a great amount of deposit around the tubes at the top of the fire box.

Mr. Beardmore remarked that one peculiarity of the tubes in the boiler to which he had alluded was that they were taper, and they could be cleaned out with the greatest facility in a very short space of time. They were 2 inches in diameter at the top, and $2\frac{3}{8}$ inches at the bottom. The 'scows,' or small barges on the Clyde, had this class of boiler. Some in use had worked for seven years without repair, although under no scientific care. To give an idea of the economical way in which these steam vessels were used, he had seen them at work on one level of 7 miles, carrying minerals between an ironwork and Glasgow. The driver's wages were one guinea a week, and a boy attended to the steering. The cargo was quickly discharged, and two journeys were made per day. Any one who wished to investigate this subject would see how the results described by Mr. Appleby bore upon the advantages of size and length of vessel and freedom of waterway. On the Rhine and

STEAM POWER ON CANALS.

TYPE OF VESSEL USED ON FORTH AND CLYDE NAVIGATION &c.

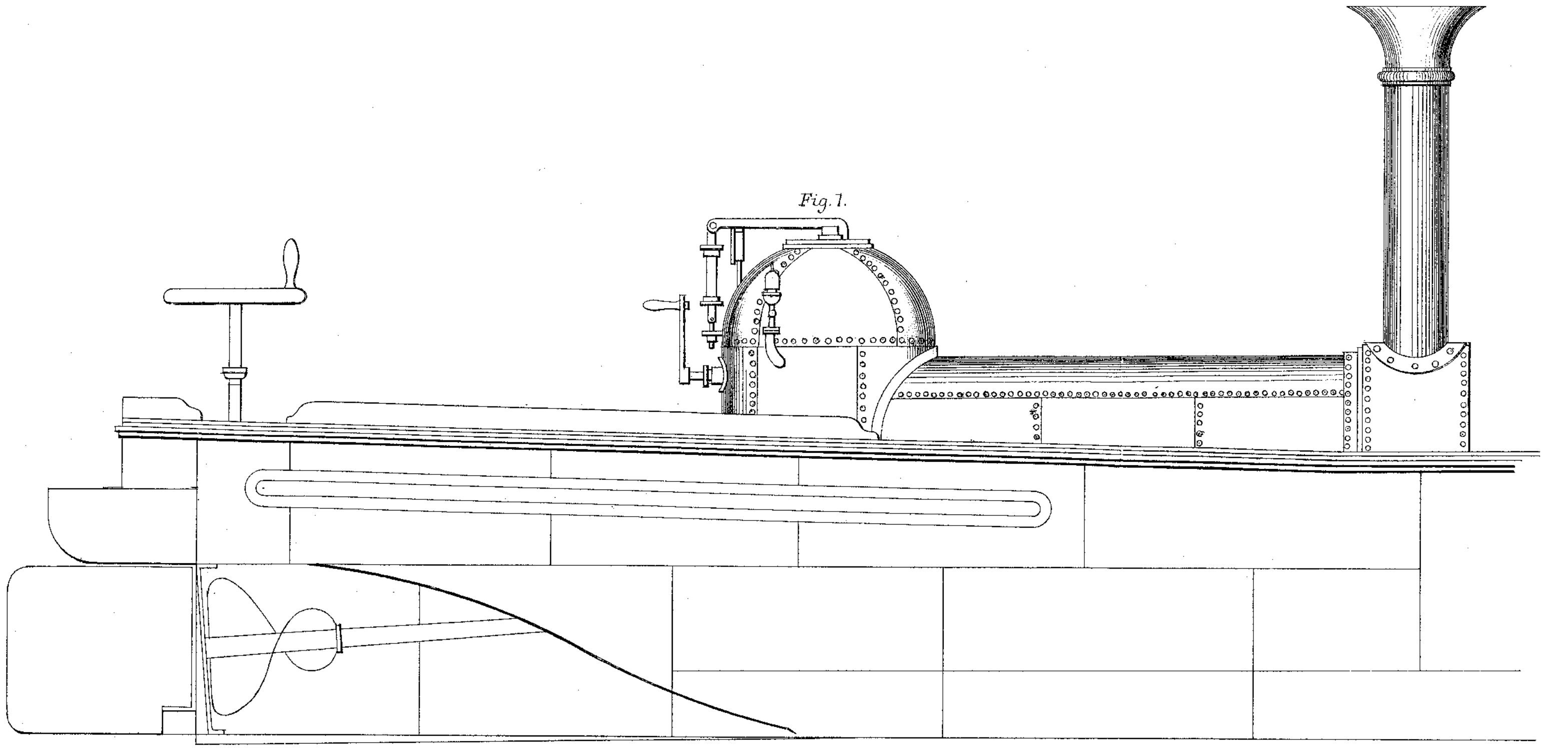


N. BEARDMORE DELT.

KELL BROS LITHRS CASTLE ST HOLBORN

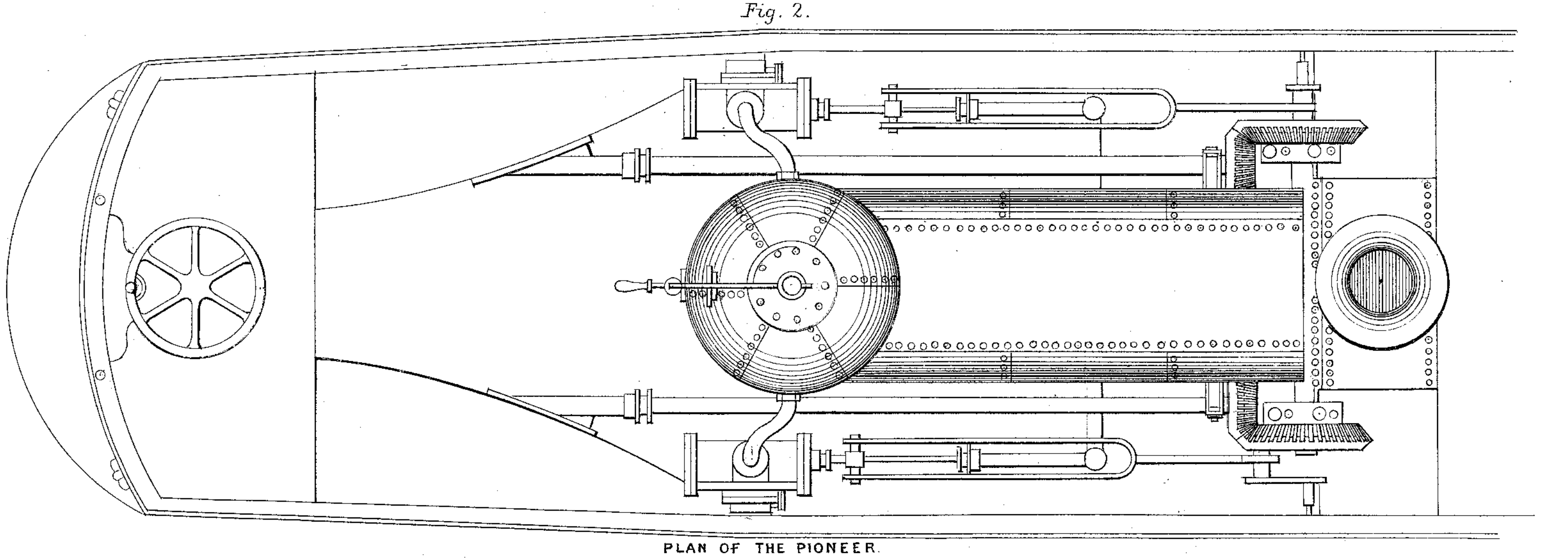
Figs. 1. 2. & 3. relate to the "Pioneer" double screw canal boat, referred to in Mr. Boardmore's remarks.
4. & 5. relate to the "Sourabaya" propeller, and as used in Holland, referred to in Mr. Appleby's remarks.

Fig. 1.



SIDE ELEVATION OF THE PIONEER.

Fig. 2.



PLAN OF THE PIONEER.

Scale

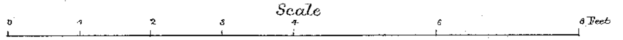
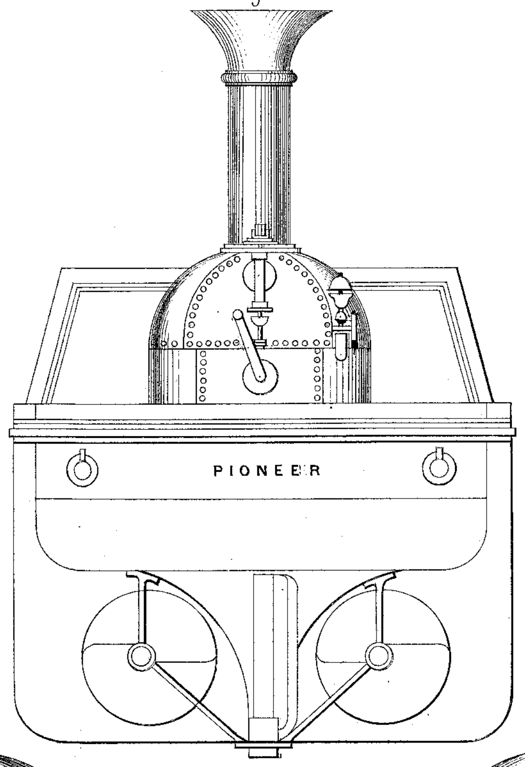


Fig. 3.



END ELEVATION

Fig. 4.

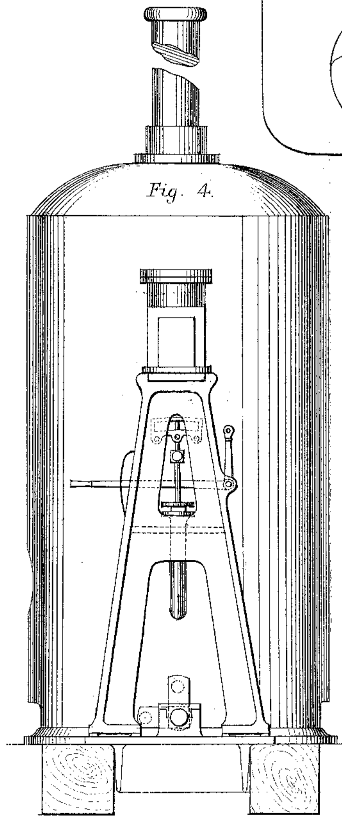
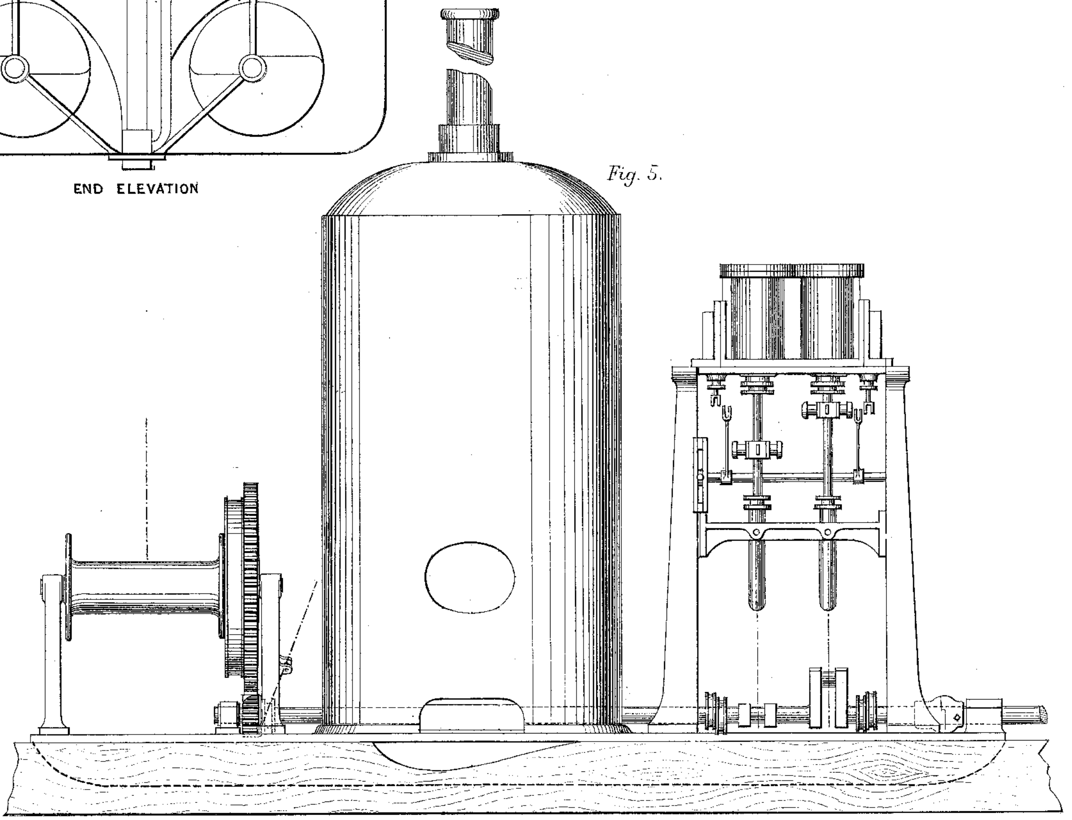


Fig. 5.



similar rivers, in addition to the ample sectional area, there was the power of using long craft, that described being 130 feet in length, or from 30 feet to 50 feet longer than could be used on any navigation in this country. This alone gave an immense advantage to the carrying power and velocity of the boat. In regard to the speed obtained on shallow canals he had arrived at the following conclusions:—First, that with any flat-bottomed vessel propelled by a screw, immersed to its full diameter in a canal where the sectional area of the vessel was less than one-seventh part of that of the whole waterway, the speed was sensibly affected (independently of the laws of motion of bodies through narrow canals), wherever the depth below the vessel's bottom did not exceed two-thirds of the diameter of the screw. Secondly, that when the sectional area and depth of the canal were less than the above proportions, the velocity at which the screw could be worked with advantage was limited by the speed with which the water could pass beneath the boat so as to feed the screw. In other words, if a speed were obtained beyond that at which the water would pass to the screw, the engine power was wasted in churning the bottom water.

November 20, 1866.

JOHN FOWLER, President,
in the Chair.

The discussion upon the two Papers, Nos. 1,154 and 1,165, on the "Employment of Steam Power on Canals," was continued throughout the evening, to the exclusion of any other subject.